Title: Evaluating the use of interactive virtual reality technology with older adults living in residential aged care

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Abstract

Background and Objectives: As technologies gain traction within the aged care community, better understanding their impact becomes vital. This paper reports on a study that explored the deployment of virtual reality (VR) as a tool to engage older adults in Residential Aged Care Facilities (RACF). The paper has two aims: 1) to identify the benefits and challenges associated with using VR with residents in aged care settings, and 2) to gather the views of older adult residents in RACF about the potential uses of VR in aged care.

Research Design and Methods: Five RACF residents and five RACF staff members took part in an intensive two-week evaluation of a VR system. Qualitative data was collected from multiple interviews and via researcher notes and video recordings made during the VR sessions.

Results: Results highlight the usability issues that impacted on the aged care residents' ability to use interactive VR technology and the potential negative impact head mounted displays can have on those living with dementia; the role that VR can play in engaging residents who might otherwise self-isolate, and how this can extend to increased engagement with family and friends.

Discussion and Implications: We discuss the design challenges that will need to be met in order to ensure that interactive VR technology can be used by residents living in aged care, and the potential for VR to be used as a tool to improve the quality of life of some older residents, particularly those for whom traditional social activities do not appeal.

Introduction

In Australia and other western countries, residential aged care facilities (RACF) provide care for those who can no longer live independently at home due to physical or cognitive impairments associated with ageing. Today, many people prefer to "age in place" or live independently at home into advanced old age, a preference that is supported by policy initiatives and funding for home-based care. When people *do* move into residential care, then, they are often frail or living with complex conditions such as dementia (Dudman, Meyer, Holman, & Moyle, 2018). A recent report found that 52% of those living in residential aged care in Australia had dementia (Australian Institute of Health and Welfare, 2017). Older adults living in aged care homes constitute only five percent of the older adult population in Australia, a proportion comparable to other western countries (Australian Institute of Health and Welfare, 2017; Center for Disease Control, 2016; Office for National Statistics, 2014). Residents of RACF are often among the most vulnerable population groups, requiring high levels of care and support, experiencing high levels of loneliness and social isolation, and suffering high rates of depression and anxiety (Australian Institute of Health and Welfare, 2017; Creighton, Davison, & Kissane, 2017; Franck, Molyneux, & Parkinson, 2016).

Responding to the challenges and complexity of aged care, RACFs offer diversional therapy and lifestyle programs that encourage residents to engage in social, creative, or fun activities. Such activities are known to be crucial for enhancing and maintaining wellbeing in old age (Greaves & Farbus, 2006). Examples of the activities offered in RACFs include visits from pets or therapy animals (Coghlan, Waycott, Neves, & Vetere, 2018), music performances, organised outings, and group games such as bingo (Khosla, Nguyen, & Chu, 2017). A recent study that explored aged care residents' reflections on their lived experiences found that residents highly valued these leisure activities (Miller, Buys, & Donoghue, 2019). However, not all aged care residents want – or are able – to engage in group social activities. The activities on offer may not appeal to residents' individual interests and some residents prefer not to take part in group activities. Living in aged care can be a lonely experience for some people, even though they are surrounded by other people (Franck et al., 2016).

In recent years, aged care providers have begun introducing technology-based activities in RACF. Robotic pets, such as Paro the seal, have been popular for some time (e.g., Robinson, Broadbent, & MacDonald, 2016), and touch-screen tablet devices have been used to support communication between residents and family members (Baker et al., 2018; Beacker, Sellen, Crosskey, Boscart, & Barbosa Neves, 2014). In addition, there is now growing interest in the use of virtual reality (VR) to enrich the lives of aged care residents. As a diversional activity in aged care, VR is particularly appealing because it can be used to: enable people to experience places and activities they can no longer experience (e.g., Hodge, Balaam, Hastings, & Morrissey, 2018), foster reminiscence (Siriaraya & Ang, 2014), and provide calming and meditative experiences, thereby addressing anxiety and agitation (Moyle, Jones, Dwan, & Petrovich, 2018).

Current commercial VR systems typically require the user to wear a head mounted display (HMD) and become fully immersed in the virtual environment. In such a system, the user's view of the physical environment around them is completely obscured and replaced by a 3D virtual world. This form of VR would typically be experienced as an *individual* activity and thus may appeal to those who prefer not to engage in group activities. Many commercial vendors now offer such VR systems for use in RACFs and in recent years, media reports and industry publications have shared positive stories about these innovations (e.g., O'Keeffe, 2016; Turner, 2017; Wood, 2016). However, there is limited academic evidence about how aged care residents and staff experience immersive VR. A recent review of the literature on VR and ageing and found that "while it was easy to find news features, it was relatively difficult to find a substantive amount of formal literature in this area" (Hughes, Warren-Norton, Spadafora, & Tsotsos, 2017 p.2), an observation that reflects our experiences of conducting research in this area. This dearth of research evidence, combined with the hype that can often be associated with the marketing of new technologies, highlights an urgent need for evaluative studies examining whether VR technology does make a positive contribution to the lives of older adults in aged care.

As a first step towards addressing this gap, this paper presents findings from a study that evaluated the use of an *interactive* VR system with residents and staff at a RACF in Melbourne, Australia. We use the term 'interactive' VR to describe a VR system that, in addition to allowing the user to view an immersive VR experience via a HMD, provides them with tools – typically via tracking sensors and hand controllers – that allow them to interact and have agency in the virtual environment. We consider an evaluation of this type of VR system to have critical advantages over less complex VR systems as it can be used to provide social, cognitive and physical engagement by allowing the user to grab and move objects, use virtual tools, and interact with avatars (virtual characters) who can be computer generated or controlled by another user (Carrasco, Baker, Waycott, & Vetere, 2017; Siriaraya, Ang, & Bobrowicz, 2014).

Five residents, aged between 74 and 88, took part in a two-week study evaluating an interactive VR system. Up to five VR sessions were conducted with each resident, each session lasting up to an hour. During this time, several virtual environments and interactive games were trialled with each participant. Qualitative data collected during the trial aimed at understanding the participants' subjective experience of, and attitudes towards, the use of interactive VR in aged care settings. Results highlight in particular the usability issues that impacted on the participants use of the interactive VR system, and the positive role that this technology can play in helping to engage residents who are disenchanted with traditional lifestyle activities offered in RACF.

Related Work: VR and Ageing

Virtual reality (VR) refers to technology that substitutes our physical environment and sensory experiences – what we might refer to as our lived reality – with an alternate digital "reality" (Fox, Arena, & Bailenson, 2009). Though research interest in VR emerged in the 1960s, it has only recently entered the mainstream as a consumer technology. The immersive characteristics of VR technology has led to it being adapted as a therapeutic tool for treating phobias, and as a means of assisting with physical and cognitive rehabilitation (Astell & Dove, 2018; Kim, Darakjian, & Finley, 2017; Maskey, Lowry, Rodgers, McConachie, & Parr, 2014; Meyerbröker & Emmelkamp, 2014; Rothbaum et al., 2014; Shiban, Schelhorn, Pauli, & Mühlberger, 2015).

These new adaptations have fuelled interest in VR technology as a tool for providing support to older adults, particularly those living in residential aged care facilities. For instance, organisations such as Alzheimer's Australia have adopted VR as a means of training aged care professionals and carers to understand the experience of living with dementia (Dementia Australia, 2016). VR has a long history of being used as a training tool in medical settings; it can be used to simulate sensitive environments that might be difficult for students to gain access to in real life (Stone, 2018). The Alzheimer's Australia example shows that VR can also be used as an educational tool by simulating the experience of living with dementia (Hayhurst, 2018). The simulation gives caregivers a first-person view showing how the physical environment can appear to people with dementia, emphasising the confusion and panic the person with dementia might experience when they, for example, try to navigate their way to the bathroom in the middle of the night.

While such an immersive VR simulation clearly has potential for fostering empathy and understanding among caregivers, virtual reality is also being used *with* older adults to allow them to transcend geographic limitations and experience new environments. The Virtual Forest is one of the few VR systems that has been evaluated in an aged care setting (Moyle et al., 2018). This is a semi-immersive environment that projects images of the virtual forest on a large-screen, rather than through head-mounted displays. Although not fully immersive, it is interactive: users can "interact with the scene through hand and arm movements" that are tracked by motion sensors (Moyle et al., 2018 p.479). A small-scale evaluation conducted with residents living with dementia found the experience was positive for most participants, but some participants found it "boring" or "confusing". These mixed results suggest that while VR experiences might show promise for providing entertainment and enhancing mood among residents in aged care, they may not appeal to all residents - just as social activities offered in aged care are unlikely to appeal to all.

In the research literature, there is a small but growing interest in the design of immersive virtual reality experiences for people living with dementia (e.g., Hayhurst, 2018; Manera et al., 2016). One recent study involved designing tailored VR experiences for a small group of participants who, while not living in residential care, did attend a local charity that provided services and activities for people living with dementia and their caregivers (Hodge et al., 2018). The study focused on designing and evaluating a bespoke VR experience for one participant. Working closely with this participant and her husband, the researchers identified music listening as a core interest for the participant. They developed a VR concert experience, which the participant clearly enjoyed: "she begins singing immediately, moves her head to look around the theatre of her own accord… laughing merrily" (p. 8). This example shows the potential for VR to enrich the lives of older adults by enabling them to engage in activities they used to enjoy but are no longer available to them. Such a use of VR clearly has the potential to expand the worlds of people living in the confined environment of residential aged care, but designing a personalised experience also requires considerable time on the part of the research team or caregivers involved in the intervention. It remains to be seen whether personalised VR can be used effectively with large numbers of residents in aged care homes. One possible alternative strategy could be to make use of the range of applications that are commercially available and to select those that best match the interests of each resident.

Beyond using virtual reality in dementia care, research has also begun to examine older adults' acceptance of, and responses to, VR as an entertainment tool. In one recent study, residents of a retirement community used the Samsung Gear VR headset to view two audio-visual VR simulations, which were both commercially available (Roberts, De Schutter, Franks, & Radina, 2019). Following the viewing experience, participants took part in a focus group discussion where they described experiencing both positive and negative emotional responses. On the one hand, they described the excitement and novelty of the experience, while on the other hand, some participants felt as though they were passive observers and that the experience provided inadequate social connectedness. These observations highlight one of the key limitations of the commercial VR experiences that are offered in aged care environments, such as those described in recent media reports (e.g., O'Keeffe, 2016; Turner, 2017; Wood, 2016). That is, such VR experiences typically involve *viewing* content but not interacting with that content. While the Virtual Forest involved some interaction using hand movements (Moyle et al., 2018 p.479), other VR systems and experiences are generally more passive. Research in this area is in its infancy and so it is not yet clear whether it is feasible to provide interactive VR experiences in residential aged care.

The study described below aimed to improve our understanding of the ways that interactive VR systems might be deployed to engage older adults living in RACF in social, creative, or fun activities and improve our knowledge about the usability issues that impact on aged care residents use of interactive VR technology.

Design and Methods

The evaluation was based on a qualitative multi-method design, which included interviews (pre and post) with residents and staff members, a visual rating instrument administered at the end of each VR session, and field observations collected during the VR sessions and the interviews (comprising written notes and video recordings). It followed an 'intensive' format in terms of timeframe, taking place in two weeks, as negotiated with the RACF due to requirements around staff involvement and internal logistics. The approach was exploratory in nature, because of the lack of knowledge on these type of interventions with a vulnerable population and in sensitive settings such as RACF. This meant relying on a small purposive sample of residents and staff members (n=10) to more thoroughly explore the topic. Additionally, recruiting participants in residential aged care environments is challenging as a result of varying cognitive and physical abilities and issues of consent (Neves, Franz, Munteanu, Baecker, & Ngo, 2015) – thus, affecting sampling and evaluation design. Nonetheless, the design allowed us to collect rich data to address our two research aims.

Research Site

The research site was a RACF located in the outer suburbs of Melbourne, Australia. The facility has 90 rooms, offering both permanent and respite care. The facility also includes a private dining room, several communal and lounging areas, a large multi-purpose space, a Ladies Parlour with sewing machines and craft tables and material, a day spa, a library, a multi-faith chapel, a Men's Shed, and four courtyards with gardens and benches. One of the four wings has a music room with a weekly live pianist as well as a multi-sensory room, designed to provide a relaxing space for residents living with dementia. The RACF lifestyle staff organise group activities such as fitness sessions, bingo, table tennis, movie matinees, and outings. The VR sessions took place in a small room that had previously been used to store physiotherapy equipment that was adjacent to the dining room and multipurpose space.

Participants

In deference to the recruitment challenges mentioned above, after receiving ethics approval, we recruited older residents in consultation with the RACF staff who were in the best position to evaluate the residents' capacities. At the beginning of the study, researchers met with RACF staff to speak about the goals of the study and the physical capacities needed to use the VR systems. Based on this information, RACF staff produced a list of six potential participants, five of whom agreed to take part in the study. Prior to agreeing to take part, each participant was given a participant information statement, and a consent to participate form, these were also read aloud to the resident in the presence of a staff member to ensure they understood the requirements of the study. During this initial meeting, participants were also asked for a date and time that would suit them best to take part in the first VR session. We took this step so as to ensure that sessions were scheduled to fit in with the routines of each participant. The study adopted an ongoing approach to consent with each participant being asked if they would like to continue to participate before each VR session in addition to signing the formal consent documents (Gupta, 2013). During the first interview with staff members they were asked about the main factors that led to them recommending the participants, this reasoning, plus basic demographic information about each participant is provided in Table 1.

Pseudonym	Age	Gender	Staff Justifications for Recommending Participants
Gail	83	Female	The lifestyle assistant described Gail as depressed, self-isolating, "set in her ways" and "a private person who can enjoy spending a lot of time in her room, often declining invitations to join activities." Gail was wheelchair bound and was described by staff as having "a mild cognitive impairment" and a history of behavioural issues.
Harry	74	Male	Harry was involved in the second week of the study (completing two sessions). Harry was unlike the other participants in that he spent several months each year in the RACF on respite rather than staying permanently. Staff felt Harry might enjoy the VR system as he did not enjoy group activities. Harry was confined to a wheelchair and suffered from Hereditary Spastic Paraparesis (HSP), a rare disorder that Harry described as being "similar to MS (Multiple Sclerosis)" that in his case "affected both [his] lower limbs".
Nancy	80	Female	Staff members identified Nancy as a resident who only engaged in select activities such as knitting or word games. One staff member noted that she did not often "deal with [Nancy] because she is kind of self-sufficient." Nancy said she didn't enjoy some activities within the RACF because they were not engaging enough. She reported being told by staff not to take part in some games in order to "give [the others] a shot". She stated "there's a couple that get offended, so I don't butt in." Nancy was confined to a wheelchair and was described as having mild cognitive impairment.

Neville	77	Male	Neville was described by staff members as having mild dementia and as being "difficult" and "depressed". Neville stated in his first interview that he felt "very isolated". Neville was very keen to show his son that he was involved in the study and told the researchers that his son was very interested in technology. Neville was confined to a wheelchair though he had a good range of movement.
Wes	88	Male	Although all the participants were described by staff as having some form of cognitive impairment, Wes was the only participant in the study with a formal dementia diagnosis. Wes reported having been a professional boxer earlier in his life, a life decision that he said he now regretted. Wes' gentle and compliant nature made him a favourite with the staff members who described him as "sweet", and "a true gentleman". Wes was confined to a wheelchair and had the most limited movement of all the participants in the study.

Table 1: Resident Participants

Prior technology experience

During their first interviews all participants were asked if they had used VR before. No participants had any experience with VR, although Nancy said that she was aware that the RACF had a VR headset but she had never used it. They were also asked whether they used any other types of computer technology in the RACF. None of the participants used technology in the RACF (e.g., tablet, P.C., Gaming console). Nancy had owned a computer previously and said she would like to use one again.

Five staff members were also recruited for the study. This allowed us to gather data about their views on the use of VR technology in a residential aged care setting and their reactions to the residents' experiences during the study. Table 2 details the staff participants' roles at the RACF and their prior experience with VR.

Pseudonym	**Role**	**Experience with VR technology prior to study (none/has seen it used/has used it)**
Lyn	*Leisure and Lifestyle Assistant*	Has seen it used
Cath	*Clinical care coordinator*	None
Craig	*Physiotherapist*	None
Bron	*Centre Manager*	Has seen it used and has used it

Fay	*Care worker*	None

Table 2: Staff Participants

VR Hardware

The VR system chosen for the study was the Oculus Rift. The system combines a head mounted display (HMD), two tracking sensors, and two dedicated touch controllers. In order to engage actively in the virtual environment, the tracking sensors are used to track head, body, and hand positioning, while the hand controllers allow the user to select items, access menus, and position the hand in the virtual environment using a combination of hand tracking and pressing controller buttons. Figure 1 shows the hand controllers and the controller buttons.

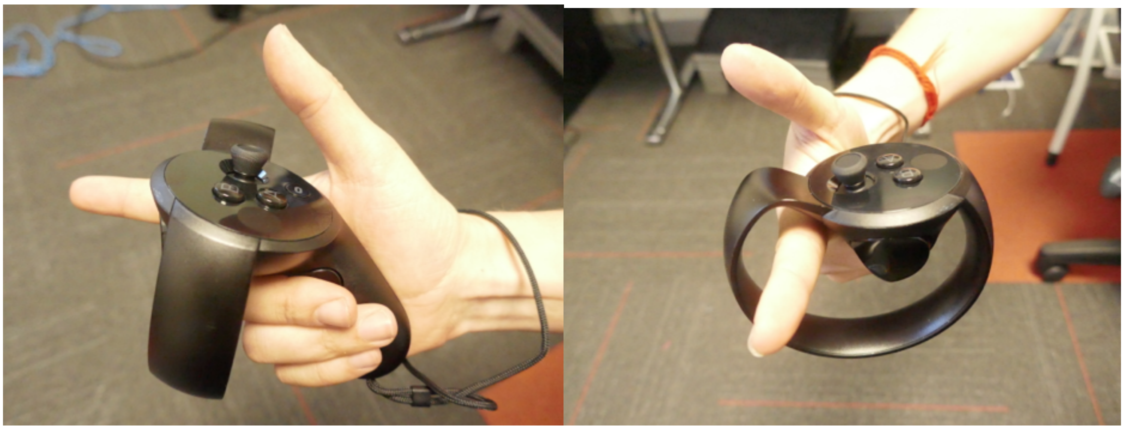

Figure 1: Hand Controllers

VR Software

A range of commercial VR software programs were used in conjunction with the Oculus Rift hardware. Two software programs (First Contact, Google Earth VR) were chosen by the research team before the study commenced. 'First Contact' was chosen as it was specifically designed by Oculus Rift to demonstrate the capabilities of the Oculus Rift system and included a tutorial that guided the user through the basic functions of the hand controllers, HMD, and tracking sensors. members of the research team had also used 'First Contact' in a prior study with older users who had spoken favorably about the software (Baker, Waycott, Vetere, & Hoang, 2019). Google Earth VR was chosen as it was a program that could give the opportunity for residents to explore a world beyond the confines of the RACF and it was felt this would offer a clear demonstration of the immersive characteristics of VR. All other software was chosen during the study to respond to specific participants preferences or needs. 'Ocean Rift' was installed in response to Neville and Wes' issues using the hand controllers (described in results section below). 'Quill', 'Toybox' and 'Power Solitaire' were installed after discussing the types of activities the participants would like to try in VR and searching the 'Rift Experiences' store to find commercial applications that would fit these needs. Each of the applications used during the study and a brief description of their key features are summarised in Table 3.

VR Program	**Description**
First Contact	• VR tutorial and interactive game. • User is guided through a brief tutorial covering the hand controllers. The user is then transported to a 'lab' and interacts with a robot

	through various activities ('grabbing' disk drives and inserting into computer/3D printer and interacting with objects such as butterflies). • Requires a moderate to high level of dexterity and mobility.
Quill	• VR Illustration tool. • User draws in a 3D environment using a variety of brushes/pens/colours and other tools. The user can 'grab' the drawing and move it in 3D space. The user can also move around the drawing by walking around. There are also pre-programmed 'tours' of 3D artwork by famous or experienced artists. • Requires a high degree of dexterity and mobility.
Google Earth VR	• VR World Tour and 3D Mapping Tool. • User chooses a specific location using the menu and is given a street-view of the address. The user can also partake in pre-programmed thematic tours, such as 'deserts' or 'cities'. • Requires a moderate amount of dexterity and mobility at street-view; Minimal dexterity and mobility for pre-programmed tours.
Ocean Rift	• Underwater Discovery Game. • User chooses a marine environment using hand controllers. Environments include 'manatees' and 'deep sea'. User is then in an immersive underwater experience whereby marine animals swim up to and around user. User can use controllers to move laterally and vertically. • Requires minimal hand dexterity and mobility.
Toybox	• Arcade Games. • User is placed into a virtual space filled with objects (blocks, firecrackers, boomerangs etc). User can interact with objects by picking up, shaking, throwing or releasing. • Requires high degree of hand dexterity and mobility.
Power Solitaire	• VR Solitaire Game. • Using hand controllers, user chooses either one or three card solitaire. User then plays solitaire against a computer. User is required to pick up and release cards using hand controllers. • Requires a moderate degree of hand dexterity and minimal mobility.

Table 3: VR Programs Used During Trial

Data Collection

Semi-structured interviews

All participants took part in semi-structured interviews at the beginning and end of the data collection period with each lasting approximately 20 minutes. This type of interview guide was selected due to its flexibility, combining open and closed-ended questions and allowing for new and follow-up questions. We opted for individual interviews – rather than focus groups – because we aimed to collect perceptions based on individual engagement with the VR environments (including exploring individual choices, needs, and aspirations) and avoid power relationships or peer-pressure in group discussions. Both resident and staff participants answered a range of questions that included their time spent living or working in the RACF, their thoughts on, and previous experience, with a range of technologies, and their thoughts on the use of VR in an aged care setting. The final interviews concentrated heavily on their experiences using the VR system and their thoughts about its applicability in RACF. The total of interview audio was 4:23 hours. Participants were interviewed by the first, third, and fourth authors; all experienced qualitative interviewers.

VR sessions

Over the two-week deployment period, the resident participants were invited to take part in up to five, one-hour VR sessions. All participants used the VR program 'First Contact' during their first session. This program was chosen as it provided a fun introduction to the VR system and was useful for enabling participants to learn how to use the hand controllers. In subsequent sessions, we introduced a range of other software programs based on the participants' stated interests and their level of confidence in using the system.

At least two researchers were present at each VR session which were video and audio recorded, resulting in a total of 7:40 hours of video footage and 4:42 hours of audio recordings. One researcher recorded observation notes during the interviews and VR sessions, while the other was on hand to assist the participant during the session and ensure they were safe while using the VR gear. At the conclusion of each session, participants were interviewed about their experience and asked to rate their experience using smiley faces (Herr, 1998).

Data Analysis

All qualitative data – video footage, audio recordings, and field notes – were transcribed when necessary and imported into QSR International's NVivo qualitative data analysis software for coding and analysis. Researchers followed Burnard's (1991) approach to thematic content analysis, which is adapted from both grounded theory and content analysis-based approaches to qualitative analysis. In accordance with this approach, two researchers undertook independent parallel coding (co-coding) of transcript data (Burnard, 1991; Thomas, 2006). These parallel codes were then compared, and adjustments to themes were made to enhance the validity of the resulting themes and guard against researcher bias (Burnard, 1991). These resulting themes were used as the basis for the discussion of the research results.

Results

Usability Issues

One aspect of the study that distinguished it from prior work was its use of *interactive* VR technology consisting of body tracking, HMD, and the use of hand controllers. These elements had the *advantage* of giving the user agency in the virtual world, however, the potential *disadvantage* was the added complexity inherent in such a system. Therefore, a key question at the beginning of the study was whether the residents who participated in the study would be capable of mastering the system to the extent that they would be able to fully engage in the VR experiences? Below we summarise how the participants responded to different elements of the interactive VR system.

Hand controls

Nancy, who was the first resident to try the system, quickly mastered the hand controls and was able to navigate even the most complex software (e.g., Quill the VR painting application that required the user to launch complex menu systems, manipulate a 3D 'virtual canvas', and use complex painting tools). Harry and Gail, though less technically proficient than Nancy, were also proficient users of the system who needed little assistance. Both Harry and Gail often worried at the start of the session that they would forget how to use the hand controllers, however, once they had a brief 'refresher' before starting the session they were competently able to navigate most software. Despite being able to use the controllers in most environments, Gail noted that the hand controllers "always felt awkward" for the duration of the study. Only Neville and Wes struggled to learn the basic operation of the hand controls. Neither Neville nor Wes was able to use the hand controls to navigate the introductory VR environment 'First Contact'. Wes in particular who had very large hands had great difficulty shaping them around the controllers saying he felt "like I'm going to drop it." The only way that Neville and Wes could complete the 'First Contact' game – which required the user to pass objects to, and interact with, a robot – was to have a researcher move their controllers for them (see figure 2). This led to a decision to focus on VR experiences that required less dexterity with Neville and Wes in subsequent sessions. As the hand controls were without doubt the most complex parts of the interactive VR system, overall, our results suggest that hand controls are well tolerated by RACF residents and that the benefits gained by giving the participants agency in virtual environments outweigh any concerns about the added complexity of such systems.

Figure 2: Neville Requiring Assistance with Hand Controllers

HMD

The HMD was well tolerated by the majority of the participants. Though Nancy and Gail stated that the HMD was at times uncomfortable after long sessions, neither described this as being a major issue. Only Wes reported any issue with the HMD. Toward the end of the study he commented that he "didn't like the head gear" saying "I feel all closed in". During an interview with Cath, the clinical care coordinator, the researchers mentioned Wes' comments, she wondered if this might be related to Wes' dementia. Cath said that she had reservations about using VR with residents who are living with Lewy body dementia (Hanson & Lippa, 2009) as she believed that the propensity for those living with this condition to experience hallucinations may lead to them finding the immersive qualities of VR distressing. Though Wes did not have this type of dementia, he was the only participant with a formal dementia diagnosis. When asked in the final interview how he felt about using the VR system he said he "[couldn't] remember much about it", and after his final VR session he described feeling as though he wanted to "punch [his] way out" of the 'Oceans Rift' experience. Given the intense research interest in using VR as a tool for engaging with people living with dementia (Hayhurst, 2018; Manera et al., 2016; Moyle et al., 2018) and the prevalence of 'grey literature' promoting the use of VR with dementia patients (O'Keeffe, 2016; Turner, 2017; Wood, 2016) we believe Wes' reactions to the use of a HMD call into question the use of HMD with people living with dementia. As such, future research evaluating the use of HMD with dementia patients is warranted.

Body Tracking

While the tracking sensors used by the Oculus System provided the ability to track the participants' movements and translate them into movement in the virtual environments, several challenges were encountered during the study. A particular challenge related to the fact that all the participants were in wheelchairs. As the wheelchairs had high armrests, participants would regularly bump into them while reaching for virtual objects. In addition to impacting on the participants VR experience, when discussing this limitation with staff they were concerned this could lead to bruising and damage to skin integrity (Jadotte et al. 2014). Figure 3 shows Nancy reaching over her chairs armrests to reach for a virtual object. One potential solution for this problem was for a researcher to take off the brakes on the wheelchair and manoeuvre the participant so that virtual objects were always directly in front, however, this solution was ruled out as taking control over movement in virtual environments is a known cause of simulator sickness (dizziness) in VR (Lin, Duh, Parker, Abi-Rached, & Furness, 2002).

Figure 3: Nancy reaches over her armrest to grab a virtual object

A secondary challenge related to the amount of reach required in some of the commercial VR software used in the study. Several of the VR programs, such as, 'First Contact', 'Quill', and 'Toybox', often had virtual objects that required the participant to reach so far that the researchers were concerned they might tip forward out of their chairs (see figure 4). To minimise the risk of overreaching, researchers carefully positioned participants' wheelchairs at the beginning of each session to be in the centre of the tracking space in order to minimise the reaching that would be required. Given that RACF residents are increasingly frail and are likely to have significant physical limitations (Dudman et al., 2018) our results suggest that future VR interventions targeting RACF residents should be designed in such a way that body tracking and movement can be adapted to allow those in wheelchairs to interact freely with virtual objects and that excessive forward movement is not required.

Figure 4: Gail reaching forward for a virtual object

Embodiment and Immersivity

One of the key advantages of VR technology is its ability to immerse the user in an alternate digital 'reality' (Fox et al., 2009). The interactive capacity of VR system used in this study added the ability to embody a virtual avatar that would give them agency in the virtual world (Carrasco et al., 2017; Nowak & Fox, 2018). Below we detail how the participants in this study reacted to the immersive nature of the VR experiences and how they reacted to having agency in the virtual environments.

In their post-session interviews, several participants reflected on the immersive nature of the VR experiences. At the conclusion of his first session using the underwater discovery game 'Ocean Rift', Neville commented that "it really feels like you are underwater". Wes, reflecting on the 'Ocean Rift' experience said that he could "just imagine how a fish feels". A common reflection after the end of the VR sessions was the feeling that the participants had lost track of time, suggesting that they were engrossed in the virtual activity. Though less prevalent in the transcripts, some participants also reacted to the sense of embodiment in the virtual environment, especially in the 'First Contact' application. After completing her initial 'First Contact' VR session, Gail was struck by how much she felt she embodied her virtual character, which she called a "machine" stating, "You know, you really think you are on top of that machine, you don't see the machine, you just see the robot and you really feel that you are able to touch it. It is virtual reality, it really is!" Reflecting on her experience, Gail said that she felt "sorry for the people here (in the RACF) that will never get to be able to see (VR)". The immersive characteristics of VR also proved challenging in some contexts, however. In her second session, Gail asked whether she could use 'Google Earth VR' to visit her former home. Using the 'street view' feature, she was able to travel up and down her street and see that the new owners of her former home had done extensive renovations. This immersive journey was tinged with sadness for Gail and she described her feelings afterwards as "good, but mixed". She reflected on the fact that she and her husband had lived there for 55 years and that "all (her) children had been born and raised there". Despite these mixed feelings, when asked to rate the experience using smiley faces, she chose 'happy' and 'excited'.

These results add to the emerging body of literature highlighting the way that the immersive nature of VR can provide a valuable way for RACF residents to have an experience of traveling to an alternate reality (Hayhurst, 2018; Hodge et al., 2018; Manera et al., 2016). Results also support the view that VR has an important role to play in addressing the loneliness, depression, and social isolation that is an acknowledged issue impacting on those living in RACF (Creighton et al., 2017; Franck et al., 2016). Gail's reaction to the embodied nature of her interactions in the 'First Contact' application demonstrate how the use of more advanced interactive VR technology, such as that used in our study, can add to the 'reality' of the experience of using VR and hint at the ways in which future interactive VR systems might be developed in such a way as to 'give back' a sense of control and agency that can be lacking in the institutional setting of a RACF. Gail's reaction to visiting her former home in Google Earth VR, however, also reminds us of the powerful emotions that can accompany immersive VR experiences and the need to carefully consider how VR experiences targeting RACF residents can deal sensitively with these reactions.

Tailoring and Sharing VR Experiences

One of the strongest themes present in the data was that the resident participants enjoyed the way VR allowed them to participate in engaging experiences that they could tailor to their interests. They often described this as standing in stark contrast to the group activities favoured in the RACF. Gail and Nancy in particular reported that they were dissatisfied with the types of social activities that were available to them. Nancy said that VR was "much more appealing" to her than the currently available activities because "it’s just hard to find somebody here that can do, and talk and... play cards with. They all fall asleep." She said that an advantage of VR was that she could interact with the content in ways that "you don’t get from everybody [in the RACF] to the level you want." We believe our results demonstrate that the ability to design interactive VR experiences that can challenge and engage with RACF residents’ individual interests is a key advantage of this technology. To help illustrate the varying ways that participants tailored their VR experiences, Table 4 summarises the range of applications used by each participant and their thoughts on which experiences they preferred during the study.

Participant	VR Software Used	Preferences
Gail	First Contact Quill Google Earth VR Ocean Rift Power Solitaire	Gail spent time using most of the software available. Her favourite application was Google Earth VR which she used to visit places of personal interest and to go on 'global tours' looking at famous landmarks. When she entered the room for her third session, she brought the address of her granddaughter in Stoke on Trent and was thrilled to 'visit' her home and then call her to tell her all about it.
Harry	First Contact Power Solitaire Google Earth VR	Harry particularly enjoyed Power Solitaire and asked if there were any other games, such as scrabble, that he could play as these games were social and helped to get people to "talk" and "interact". As with Gail, Harry also brought in an address he wanted to visit using Google Earth VR. While Harry is in respite, his wife travels for extended periods of time. This year, his wife was visiting Spain and Morocco, among other places, and thus Harry requested to "visit Morocco because my wife is there at the moment…with this thing, I can say 'well, I didn't see you!'" He joked that "she'll say 'I can't get away from you, can I?'" In this way, Harry anticipated being able to share an experience with his wife, despite being thousands of kilometres away.
Nancy	First Contact Quill Ocean Rift Google Earth VR Ocean Rift Power Solitaire Toybox	Nancy was the participant who was most adept at using the VR system and she tried all the VR software that was available. Her favourites were First Contact, Toybox and Power Solitaire. She had great fun interacting with the robot in First Contact who she called her "little mate". She spent the most time in Power Solitaire as she loved games but commented that she would like to combine the interaction from First Contact with the skill of Power Solitaire. Nancy, who had been a recreational painter prior to entering the RACF, was very interested in using the VR painting game Quill, however, she felt the software was not ideal as it was difficult to navigate around a 3D painting while in a wheelchair.
Neville	First Contact Ocean Rift	Neville used the software First Contact and Ocean Rift, though he continued to have trouble using the hand controllers which he found frustrating.
Wes	First Contact Ocean Rift	Although he used First Contact, Google Earth VR and Ocean Rift, he spent the most time using Ocean rift as it required less dexterity with the hand controllers.

Table 4: VR applications used by participants

Sharing the VR experience

In addition to the participants using VR to engage with family members through virtual travel, Gail and Nancy reported proudly sharing their experiences with their families in real life. Nancy commented "I wanted to go and brag to everyone that I'd done it", which she subsequently did. Gail similarly said "I told the kids about where I travelled", and when asked how they responded, she said "[they asked] 'what was it like Mum?' I said, I can't describe it. It was fantastic." In this way, Gail was able to share her virtual travels with her family, which gave her a sense of pride at having experienced something—while in a RACF—that they had not. Although Neville withdrew from the study before it was completed, he brought his son to an earlier VR session so that he could experience the VR. This was a further example of VR being a conduit for family interaction. There was also evidence that the participants wanted to share the experience with other residents. Gail, in particular, spoke several times about being sad that others in the RACF were not able to experience VR and at the end on one session encouraged the researchers to show Google Earth VR to Wes saying "Make him do (Google Earth VR), it's just great".

When asked about what sort of experiences they would like to have in VR in the future, many participants also spoke about the potential to have social experiences with people outside the RACF. Gail was enthusiastic about the idea of a socially interactive game that would allow her to play a card game, such as Solitaire or 500, with her family members, friends or strangers. Nancy was similarly interested in the potential for socially interactive card games, and Harry suggested socially interactive versions of games such as Scrabble would allow him to engage in conversations. He lamented that in the RACF many residents are not capable of having a discussion with him.

While VR is often described as an individual experience, our results suggest that VR can act as a powerful tool to provoke social interaction and thus counteract the high levels of social isolation prevalent in RACF (Franck et al., 2016). Moreover, participants' thoughts about the types of future VR experiences they would value demonstrates that many focussed on VR software that would allow genuine social interaction in a virtual environment, a topic that is beginning to be considered in the literature examining older adults' use of VR (Baker et al., 2019). This result is particularly significant given that many of our participants were catagorised by staff as being 'self-isolating', 'difficult', and 'depressed' (see Table 1) and we are excited by the potential for future research to examine social interactions in virtual environments using interactive VR.

Discussion and Implications

One of the major goals of our study was to gain a better empirical understanding of how VR, particularly more complex interactive VR systems, could be used by residents in RACF as a creative, fun, and engaging form of social activity. Our study contributes new knowledge about how RACF residents responded to the interactive VR system, the benefits they believed such systems could bring, and the challenges that will need to be met in order for future interactive VR systems to contribute to their wellbeing. In particular, our results contribute to our understanding of the usability issues that can impact on aged care residents' enjoyment of interactive VR, and the ways in which interactive VR can provide ways to engage residents who find traditional group social activities unappealing.

Usability of Interactive VR in RACF

Fronemann, Pollmann, Weisener, and Peissner (2016, p. 6) highlight the "importance of factors such as accessibility, desirability, benefit and acceptance when designing technology for older adults", and our results relating to the usability of interactive VR technology add to our knowledge about the important design considerations that will need to be addressed in order to make interactive VR systems respond to the needs of RACF residents.

In order to have agency in a virtual environment, RACF residents need to be provided with a means to use their hands to interact with virtual objects and avatars. The most common means of achieving this requirement using existing VR systems is to use hand controllers, such as those use in the Oculus Rift system used in this study. While three of the five participants in our study were able to master the hand controllers sufficiently to engage with a wide range of VR software, Wes and Neville struggled with the hand controllers to the extent that they were only able to interact with in VR in very simplified environments, such as the underwater experience 'Ocean Rift'. The complexity of the hand controllers and issues relating to the use of the controllers when the user has large hands were key results of our study. Given these issues, future research that considers more natural interaction methods, such as the use of 'haptic gloves' that track hand movements and provide additional feedback about virtual objects, are warranted (Perret & Vander Poorten, 2018).

Our results also sound a note of caution about the use of VR systems that rely on HMD with RACF residents living with dementia. While the small sample size of our study does not allow us to make any broad generalisable claims, Wes's experiences, and the comments of clinical staff, suggest that any interventions using HMD with those living with dementia should be carefully planned and evaluated. Wes's comments about disliking wearing the HMD and statement that he forgets about his experiences between sessions, combined with his unease directly after using the HMD on some occasions were issues of concern. Our view is that research should be conducted to thoroughly examine the use of HMD based VR interventions with people living with dementia. Particular emphasis should be placed on assessing how to measure distress during a VR experience given that Wes' compliant nature and lack of physical signs of distress made assessing his VR experience difficult. Until such time as this research is undertaken, semi-immersive systems that rely on projected virtual environments rather than HMD such as those used by Moyle et al., (2018), may be more appropriate when introducing VR technology to residents with more advanced dementia symptoms.

Interactive VR and Self-Isolating Residents

Our results suggest that that the heterogeneity of RACF residents is so great that current modes of engagement, particularly group activities that are targeted to the capabilities of less physically and cognitively able residents, are inadequate for some. Interactive VR may prove to be a valuable tool for engaging this cohort of residents. Most of the participants in this study were identified as self-isolating and generally withdrawn from social activities: results demonstrate that their reasoning for these behaviours centred around feeling uninterested in the available activities.

For these residents, traditional RACF social activities are simply uninteresting or unengaging. This illustrates the conundrum faced by some RACF residents: being surrounded by others, yet unable to engage in meaningful interaction because of the physical or cognitive issues impacting their peers. They crave a richer type of interaction and stimulation which was provided by the interactive VR system. According to Fees, Martin and Poon, the perception of inadequate relationships inherent in loneliness "may be the consequence of a lack of stimulating interaction" (Fees, Martin, & Poon, 1999, p. 237). This emerged as a recurring theme in the participants' responses and attitudes when reflecting on their use of VR. The potential to design VR experiences that cater specifically to this subset of residents is great and our results provide empirical evidence supporting the role that interactive VR can play in engaging these self-isolating residents. It is worth emphasising that our participants self-isolating behaviour did not appear to be related to being anti-social. For example, when asked for her thoughts on a potential system that would allow her to play card games with people outside of the RACF, Gail said "oh that would be wonderful. Magic. It would be like we were together, even though we're not." Gail felt that VR would help break up the monotony of life in RACF: "especially if you're in a place like this where you are on your own a lot of the time, and your head is talking to you…It would be good to get out of that and do this sort of thing."

Limitations

While our study had contributed to improving our understanding of how interactive VR might play a role in improving opportunities for social activities for aged care residents, the study faced a number of limitations that can be addressed in future research. While the small number of participants and qualitative nature of our study suited its exploratory nature, larger cohort studies across multiple RACF using a mixture of research methods will be needed to ensure that our results are supported by more generalisable findings. The current study was also limited in duration in order to accommodate the needs of the partner organisation who supported the study. Longer term evaluations of VR use in RACF will be required to better understand the challenges associated with long-term use of VR by aged care residents. Finally, although we have discussed the challenges relating to deploying new technology in RACF elsewhere (Cavenett et al., 2018), researchers evaluating the use of VR by aged care residents will also need to understand the challenges involved in implementing and integrating VR systems on to existing lifestyle programs. Particular emphasis on issues such as; system management (e.g., ensuring software is up-to-date), providing ongoing training, and ongoing software development will be key to ensuring that VR technology can be successfully integrated into the dynamic workplace environment of RACF.

Conclusion

Virtual reality (VR) is a technology that is increasingly being used in residential aged care facilities (RACF), however, little empirical evidence exists investigating the challenges and benefits of this technology in the context of aged care. In this exploratory study, we sought to begin to address this gap by conducting a qualitative evaluation of an interactive VR system with five RACF residents aged between 74 and 88. Over a two-week period, participants took part in up to five VR sessions lasting up to an hour. The study aimed to improve our understanding of the ways that interactive VR systems might be deployed to engage older adults living in RACF in social, creative, or fun activities and improve our knowledge about the usability issues that impact on aged care residents use of interactive VR technology. A range of commercial VR technology was used during the VR sessions and data, including video footage, semi-structured interviews and researcher diaries were collected and analysed. Results demonstrated the range of usability issues that can impact on older adults ability to engage effectively with interactive VR technology, the types of VR experiences that were most valued by the participants, and their views on how future VR technology might be used to provide them with engaging activities. Our results also suggest that caution may need to be exercised in deploying VR systems, particularly those employing head mounted displays (HMDs), with residents living with dementia. This finding is particularly relevant given the intense interest in employing VR for residents with dementia in RACFs. This study also indicates that VR may be one way to provide stimulation and engagement to improve the quality of life of some vulnerable older adults in RACF for whom traditional social programs lack appeal. Given the enthusiasm expressed by participants about the potential for VR to contribute positively to their lives, this study adds to our knowledge about the types of VR systems and experiences that can best meet older adults needs.

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